

# **TRANSFUND NEW ZEALAND**

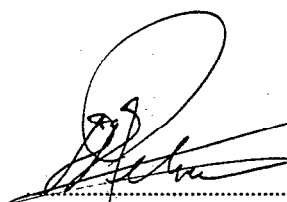
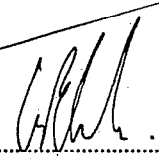
## **REVIEW OF SAFETY AUDITS OF ROUNABOUTS**

Review and Audit Division  
Report No. RA96/559S

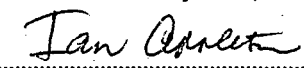
# TRANSFUND NEW ZEALAND

## REVIEW OF SAFETY AUDITS OF ROUNDBABOUTS

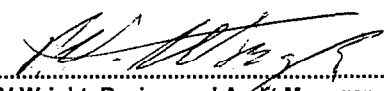
Prepared By

   
.....  
Dave Petrie and Gary Clark, Traffic Design Group, Lower Hutt

Reviewed By

  
.....  
Ian Appleton, Safety Audit Manager

Approved By

  
.....  
P V Wright, Review and Audit Manager

June 1998

## **PREFACE**

This is a final report. A peer group has reviewed a draft of the report. It has been modified to take account of the comments of that group.

The report contains the findings, opinions and recommendations of the reviewer based on an examination of a sample of audit reports only. As a consequence the review may not identify all features of all audit reports.

This report has been prepared for the purposes of assisting Transfund New Zealand to discharge its statutory responsibilities and to provide advice to the authorities concerned.

While every effort has been made to ensure the accuracy of the report, it is made available strictly on the basis that anyone relying on it does so at his/her own risk without any liability to Transfund New Zealand.

## TABLE OF CONTENTS

1. INTRODUCTION .....	1
2. SAFETY AUDITS FOR STATE 1 AND STAGE 2 .....	4
3. STAGE 3 (FINAL DESIGN) .....	6
4. STAGE 4 (PRE-OPENING) .....	8
5. STAGE 5 (POST-OPENING).....	11

## 1. INTRODUCTION

This report summarises the results of a selection of roundabout safety audits as requested by the Safety Audit Manager for Transfund.

The purpose of the review is to provide feedback to practitioners involved in the design of roundabouts from the concept stage through to detailed design and implementation. This is intended to then alert the profession to the elements that need particular care in the design phases so as to avoid the typical problems highlighted by the audits.

This review has considered 50 audit reports, looking at the issues and problems raised by the various auditors. It is not a review of the auditors' techniques. Information shown in the form of graphs and percentages has been summarised from the sample of audit reports and does not represent a vigorous statistical analysis.

Initially, it was intended to review only roundabout audits from the 1995/96 National Roding Programme, but in order to obtain a more representative sample, the period was extended so as to also include audits from earlier years, including some of the pilot audits undertaken when the audit process was introduced. The review period was from 1991 to 1997.

Safety audits can be undertaken at the end of each significant phase of the design process and through to post-construction, as follows:

- Stage 1 Audit, at the "Feasibility" stage
- Stage 2 Audit, at the "Project Assessment stage"
- Stage 3 Audit of the "Final Design"
- Stage 4 Audit ("pre-opening") following completion of construction.

This report also refers to "Stage 5" audits, being the term used in this report to represent any audits of recently constructed roundabouts during normal

operation. It is noted that the procedures for undertaking the Stage 1 to 4 safety audits are outlined in Transit NZ's "Safety Audit Policy and Procedures", August 1993.

There are no procedures set down for "Stage 5" audits and these audits of existing roundabouts typically relied on applying the same procedures as for the Stage 4 safety audit.

Stage 1 and 2 audits typically cover a wide range of issues, mainly of a general nature. This would be expected because of the preliminary nature of the projects. As these roundabout projects progress from preliminary design to detailed design and implementation, the audit reports are more specific about matters of detail.

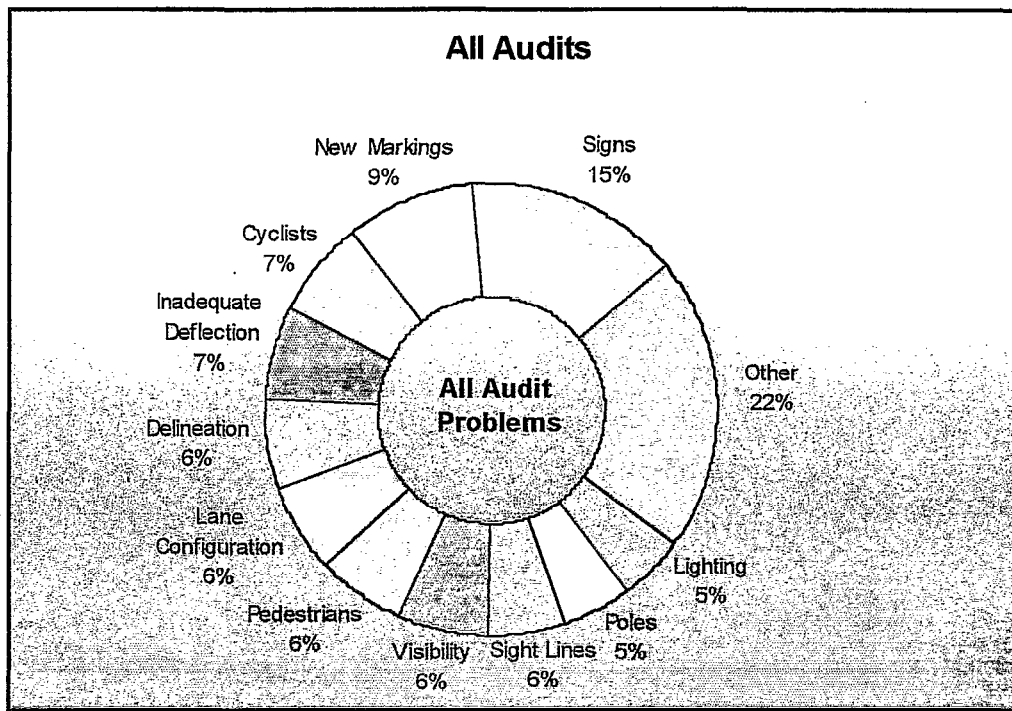
For convenience, the more common issues and problems identified during the audit process have been grouped together and highlighted for each phase of the audit process (Stages 1 to 5). However, the outcomes for Stages 1 and 2 have been grouped together because of the more limited number of these audits available for review. The distribution of audit types that were evaluated is then summarised in the following Table 1.

**Table 1 : Distribution of Roundabout Audits by Type**

STAGE OF AUDIT	No OF REPORTS EVALUATED	SPEED ZONES			STATE HIGHWAY	LOCAL AUTHORITY ROAD
		50 km/h	70 km/h	100 km/h		
Stage 1	1	1	-	-	-	1
Stage 2	11	9	2	-	11	-
Stage 3	13	8	2	3	8	5
Stage 4	14	8	2	4	9	5
Stage 5	11	4	5	2	2	9
TOTAL	50	30	11	9	30	20

Figure 1 shows the problems highlighted in all audit reports.

**Figure 1 : Problems Highlighted in all Reports**



As shown 11 key issues accounted for 78 percent of the reported problems across all of the 50 audited roundabouts. The remaining 22 percent of identified problems included a further 10 miscellaneous problems.

A number of audits raised issues that need consideration in all stages of the design and construction of new roundabouts, as follows:

- A Traffic Management Plan for the works from the design though to the completion of the project. This would provide a safer environment for not only the design and construction staff, but also for all road users. These types of intersection improvements can create a number of potentially hazardous situations in the course of construction that a Traffic Management Plan could foresee and address.
- Advance Direction Signs need to be included with most roundabout projects, particularly at major sites. They are seen as providing an

important warning which will enable the approaching motorists to take the appropriate course of action

- Old roadmarkings can spoil the effectiveness and appearance of a new constructed roundabout. Some roadmarkings and rrpm's that have not been removed have the potential to direct motorists into the path of oncoming vehicles. All redundant markings should be permanently removed!
- Chevron boards seemed to be a particular issue raised in most reports. Designers appeared to have focused on the approaches to the roundabout and invariably overlooked the importance to the motorists of being able to see the central island, particularly at night. The most important part of a roundabout is the size and location of the centre island and designs need to reflect its importance.

Approach and departure deflections particularly at urban roundabouts were considered to be less than desirable and often inadequate. Adequate deflections are particularly important in higher speed environments as, for instance, on local urban arterials or remote from central urban areas.

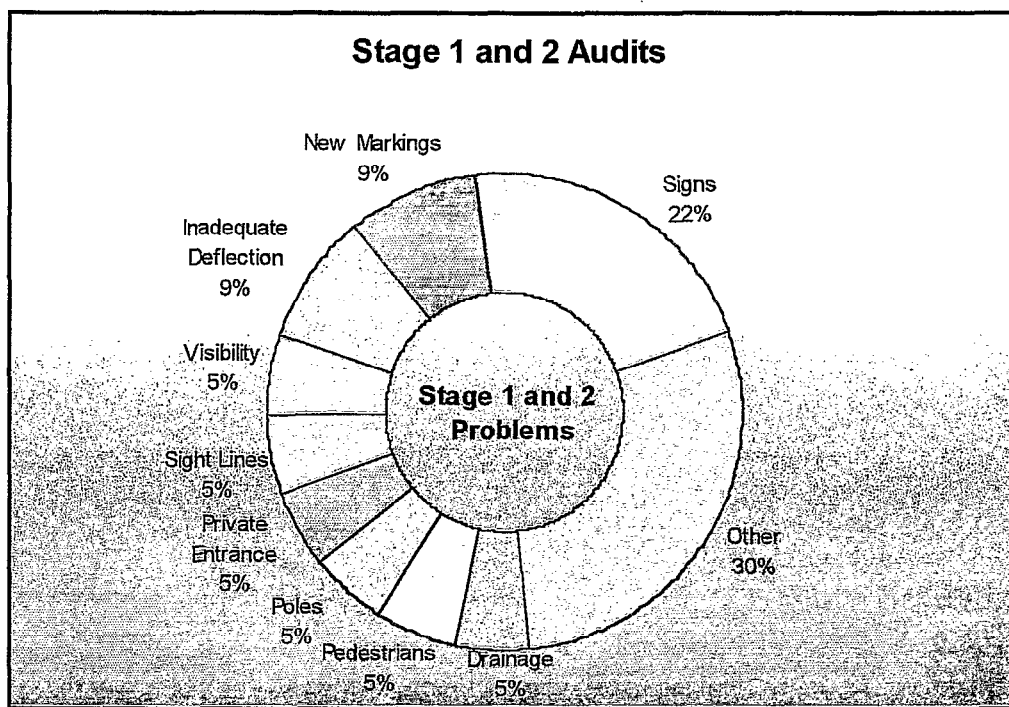
## 2. SAFETY AUDITS FOR STATE 1 AND STAGE 2

There were a total of 12 stage 1 and stage 2 audit reports available for review, covering the period from 1993 to 1996. Ten of these reports were for roundabouts within an urban area and the remaining two were in a 70 km / hr area.

80% of these audit reports were for roundabouts on a State Highway

The results from the Stage 1 and 2 roundabout audits have been grouped together by common topic and summarised diagrammatically in Figure 2, as follows:

**Figure 2 : Problems Highlighted in the Stage 1 and Stage 2 Audits**



These audit reports raised a number of issues that require attention. As shown in Figure 2, there were 9 different matters which were common to a number of the audits and which accounted for 70 percent of the identified problems. A further 13 less commonly identified problems made up the balance.

Auditors used their experience to assess those aspects of the proposed design where potential problems could occur. The main issues were:

- lane markings confusing and misleading
- the number of exit lanes unequal to entry lanes.

These deficiencies were considered by the auditors as encouraging vehicles to travel through roundabouts at inappropriate speeds and to create areas of conflict caused by misleading information and road design. Other main issues included:

- inappropriate or inadequate lighting
- inadequate deflection through the roundabout and/or its approach and departure deflections provided poor or inappropriate guidance into and out of the roundabout. Guidance on the appropriate deflections can be ascertained from the Austroads Guidelines for Roundabouts

In the matter of lighting, it was frequently noted that the lighting designs appeared to lead motorists through a roundabout rather than around it. It was typically recommended by auditors that the "target value" of the island be increased and the message of discontinuity be emphasised to the motorist in the form of chevrons and / or central island lighting.

Other matters of design about which auditors raised concerns in the Stage 1 and 2 audits included:

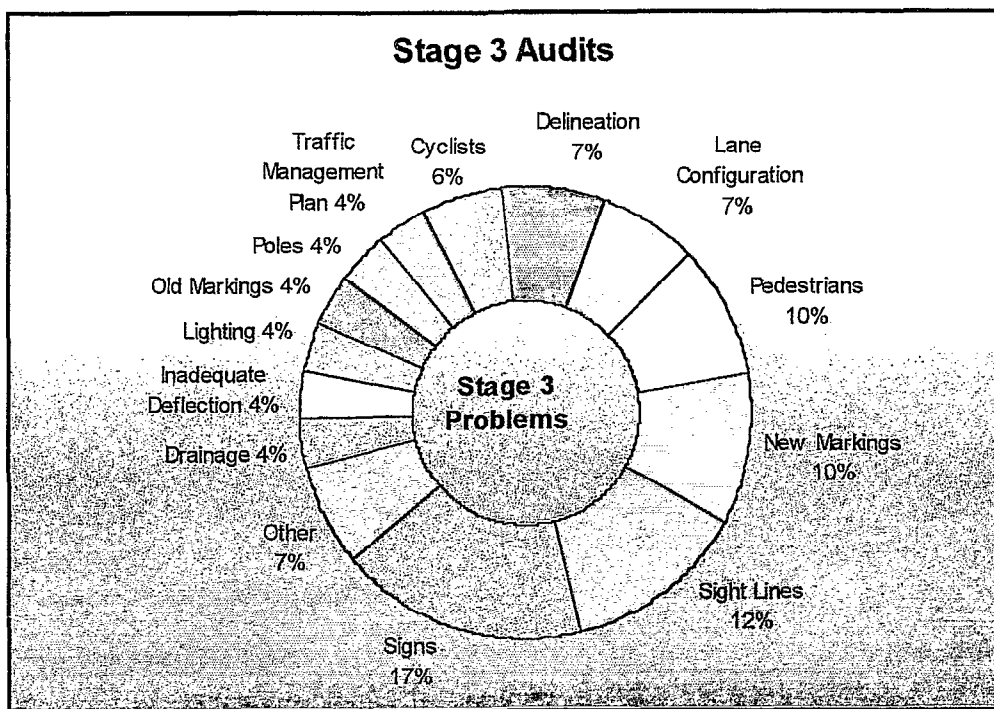
- visibility/sight distances
- road surface
- pole location/frangibility
- height of central island
- splitter islands, and
- approach speeds.

### 3. STAGE 3 (FINAL DESIGN)

There were a total of 13 Stage 3 reports made available from audits undertaken between 1993 and 1996. Eight of these reports were for roundabouts located within an urban area, two within a 70 km / hr area and the remaining three in a 100 km / hr area.

The following Figure 3 illustrates the frequency of occurrence of the various problems which were identified at the final design stage.

**Figure 3 : Problems Highlighted in the Stage 3 Audits**



As shown in Figure 3, problems with signs were the most frequently occurring. Problems to do with sight-lines, new-markings and pedestrians were also over-represented. As shown, a total of the 13 more commonly identified problems made up 93 percent of the reported problems. Designers could therefore usefully give more attention to these matters. Specifically, they included:

- inappropriate new pavement markings or the lack of them
- problems with lane configurations, specifically marking of multi-lane roundabouts
- inadequate deflection
- visibility constraints, ie
  - across the central island (due to island height) and where there was potential for the motorist's view of approaching vehicles to be obstructed, and

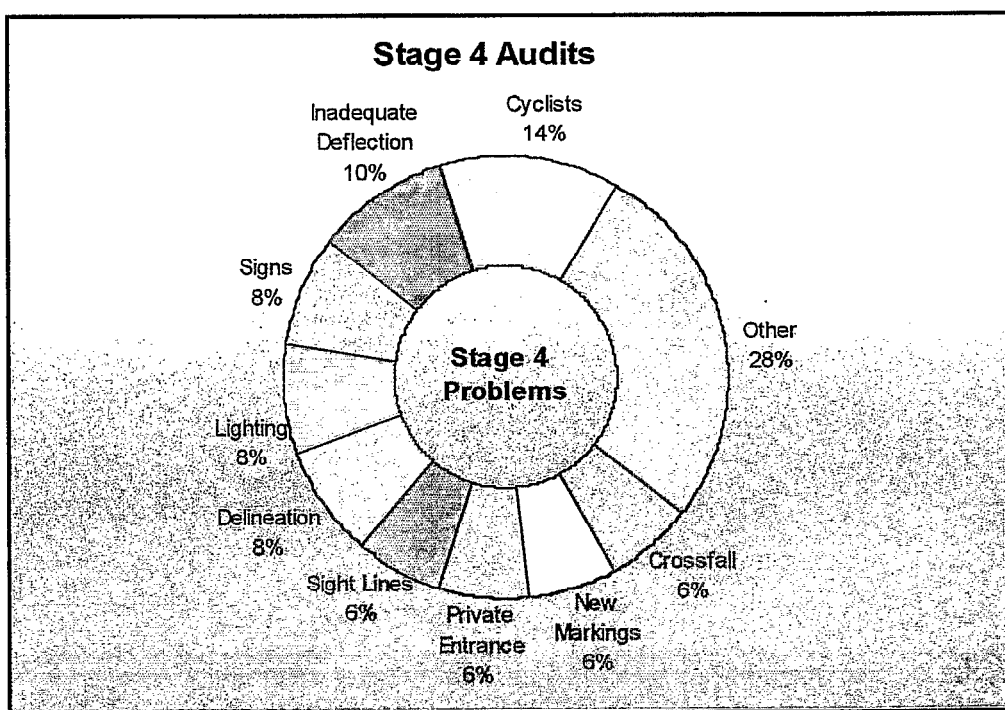
- across vegetation (where there were concerns on the type and potential heights of vegetation limiting sight lines)
- from fences along property boundaries
- parked cars

In relation to marking of roundabouts, there was a general plea from auditors for consistency, particularly within a local authority area or along a particular route (eg State Highway). There was also an expressed view that guidelines and education of the motoring public on how to use roundabouts would be desirable.

#### 4. STAGE 4 (PRE-OPENING)

A total of 14 Stage 4 audit reports were reviewed, covering the period from 1993 to 1996. Eight of these reports were of roundabouts within an urban area, two were in a 70 km / hr area, and the remaining four were within a 100 km / hr area.

**Figure 4 : Problems Highlighted in the Stage 4 Audits**



As shown in Figure 4, nine key issues accounted for 72 percent of the reported problems. Of these, it was notable that the five most dominant issues accounted for 56% of the problems. A further 11 other miscellaneous problems made up the balance of 28% of the identified problems.

As shown, the main issues were: -

- insufficient attention to the needs of cyclists (14%)
- inadequate deflection (10%)
- signs (8%) and delineation (8%)
- Lighting (8%)

In addition to these key areas, some of the particular problems quoted included:

- lack of deflection created by splitter islands (on the one hand, it was noted that the kerb and splitter island alignment did not create a smooth transition for the deceleration of approaching vehicles, and on the other hand the relationship between the approach geometry and the central island was poor, with motorists being provided conflicting information)
- visibility of roadmarkings. Due to the crossfall associated with the central island, the "Give Way" markings were often difficult to see
- trends such as grey and white pavers used in central islands to imitate chevron signs can be difficult to see at night (lack of contrast).

Auditors typically agreed that the central islands should have raised reflective pavement markers (rrpms) and low profile chevron boards and / or reflectorised paint to improve night time visibility (without restricting visibility across the roundabout)

- marking of multi-lane roundabouts is an area of debate and confusion.

Several auditors commented that the Land Transport Safety Authority needs to develop guidelines, and to educate the public on the use of roundabouts

- a lack of roadmarkings guiding motorists away from kerb extensions.

Night time delineation of roundabouts was seen as a particular problem. Few roundabouts incorporated rpms, edgelines and / or new lighting as a complete package in solving night-time problems

- confusing road markings/poor attention to detail

With the introduction of new roadmarkings, the old ones were often not removed permanently

- restricted cycle paths

Cyclists were often restricted by space provided around the roundabout. Auditors also felt that the placement of sumps had not considered the needs of cyclists, and that cyclists were generally ignored in the geometric design of roundabouts

- problems with signs

Typically, advance warning signs appear to be an after-thought with signs badly located behind buildings, other signs or trees. Size of signage is not consistent with speed environment. Direction signs along with street name plates must also be considered as an important element in guiding the motorists approaching a roundabout

- lack of proper attention to pedestrians

The lack of guidance in the provision of safe pedestrian routes though the new roundabouts, (ie pedestrian ramps were not provided at key locations,

and where ramps were provided there were likely to be drainage problems). Auditors again felt that the needs of pedestrians were generally being forgotten or ignored.

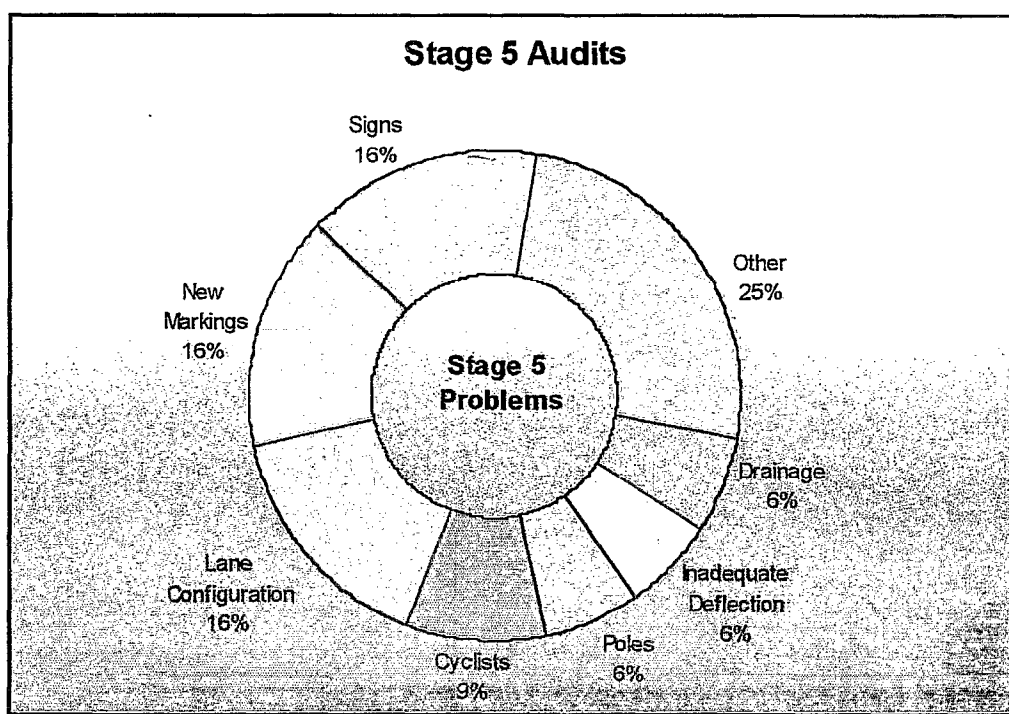
5. **STAGE 5 (POST-OPENING)**

Where audits were carried out after the roundabout had been opened for use and all the proposed works had been completed, these have been referred to in this report as "Stage 5" audits.

A large percentage of roundabouts for which a Stage 5 was audit carried out had not been audited during the design phases. As a result, a number of problems raised by auditors could readily have been addressed in earlier audits. The completed roundabouts that were reviewed progressively through the design phase required only minor cosmetic changes arising from a Stage 5 report.

There were a total of 11 Stage 5 reports made available for review from the period 1991 to 1997. Four of these audits were within an urban area, five in a 70 km / hr area, and two were in a 100 km / hr area.

**Figure 5 : Problems Highlighted in the Stage 5 Audits**



As shown by Figure 5, seven main issues accounted for 75 percent of the reported problems. A further 14 other miscellaneous problems made up the balance of 25 percent of less commonly reported issues. More specifically, the elements that auditors commented on in particular included: -

- signs missing or badly located on approaches
- missing chevrons in the central island.
- warning signs mounted too low on posts creating problems with visibility at intersection
- height of vegetation, (particularly in the central island), reducing the visibility across the roundabout.

Auditors typically noted that vegetation around the site of the roundabout was also an area of particular concern, with some plants already obscuring sight-lines at the time of the audits, and others having the potential to grow rapidly and intrude on critical sight lines

- lane markings too short leading into roundabout.

It was frequently noted that new roadmarkings were not completed properly with edgelines finishing short of the roundabout. Lane markings within the roundabout were often needed to guide motorists. The general standard of road markings was poor (although it is recognised that there is some confusion within the profession about how to most appropriately mark a multi-lane roundabout (eg Alberta markings, or not?).

Acceptable guidelines therefore need to be developed to encourage better lane utilisation both within the roundabout and on the approaches

- poor delineation though the new roundabout was also considered, especially during the hours of darkness. The absence of rrpm's and edgelines made it difficult for motorists to enter the roundabout in the appropriate position and at a safe speed
- old markings not removed as part of the project

Failure to remove old markings has frequently created or has the potential to create confusion for motorists. Old centrelines and rrpm's can potentially lead motorists to the wrong side of splitter islands.

## Glossary of Terms for Graphs

Crossfall	the amount of slope applied to the road to enable water to run off
Visibility	includes where visibility is obscured by signs, fences, buildings and/or parked vehicles, and where visibility is restricted or is likely to be restricted specifically by vegetation
Signs	all signs such as warning, regulatory, parking and directional signs
New Markings	painted markings as part of the new roundabout
Old Markings	painted markings associated with old intersection layout
Inadequate Deflection	the lack of deflection applied at the entry and exit portions of the roundabout
Cyclists	refers to amenities/facilities (or lack of them) that are required for cyclists and/or any impediments to cycling
Pedestrians	refers to amenities/facilities (or lack of them) that are provided for pedestrians and/or impediments to pedestrian use
Drainage	the ability of the drainage system to remove water from the new layout
Appropriate Measure	where the auditors have questioned whether the designer has evaluated the type of intersection control correctly

Lighting	the amount of lighting provided and its location
Private Entrances	vehicle entrances located near or within the roundabout
Delineation	measures other than painted lane-markings such as raised reflective pavement markers (rrpms), flush medians, also chevron boards etc which are used to guide motorists through new roundabout
Traffic Management Plan	a plan which is formulated in order to manage traffic safely throughout the construction works
Lane Configuration	intended lane utilisation in relation to traffic volumes as described by the road markings
Road Surface	type of material laid and its condition
Poles	refers to all service poles, as to their location and/or frangibility
Central Island	the location, height and diameter of the central island
Splitter Island	the location, height and shape of the splitter islands
<u>Other Matters:</u>	
Sight Lines	as used to review visibility of approaching vehicles as defined by the Austroads Guidelines for Roundabouts
Approach Speed	the speed of approaching vehicles

